MICROFLUIDIC DEVICE FOR PASSIVE SORTING AND STORAGE OF LIQUID PLUGS USING CAPILLARY FORCE

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims a benefit of priority under 35 USC § 119 based on patent application 60/939,944, filed May 24, 2007, the entire contents of which are hereby expressly incorporated by reference into the present application.

STATEMENT AS TO RIGHTS TO INVENTION(S) MADE UNDER FEDERALLY-SPONSORED RESEARCH AND DEVELOPMENT

[0002] The U.S. Government, through the National Institute of Standards and Testing, is the owner of this invention.

BACKGROUND OF THE INVENTION

[0003] 1. Field of the Invention

[0004] The present invention relates in general to the field of microfluidics. More particularly, the present invention relates to a three dimensional (3D) microfluidic device for the passive sorting and storage of liquid plugs using capillary force.

[0005] 2. Discussion of the Related Art

[0006] Sorting and storing microfluidic droplets is a subject of high importance for a number of different applications. One field is protein crystallization. For example, the group of Prof Ismagilov at the University of Chicago creates droplets with different contents of the reagents necessary to crystallize proteins. In this approach, the contents of each droplet are modified to enable screening through a large combinatorial set of reactions to determine the best combination of reagents for protein crystals. After production, the droplets need to be stored in a deterministic way so that the contents of each stored droplet are known. The initial solution to the problem of sequential storage was to introduce a glass capillary on a microchannel, fill it with a sequence of droplets, take it out, seal it with wax, and connect a second capillary to the outlet of the device. This operation proved cumbersome as the capillaries needed to be filled sequentially, labeled, and then stored many times. More recently, a simpler way to perform this operation by running the generation of droplets into very long tubing until it was filled was demonstrated.

[0007] Another method to store sequentially droplets for combinatorial experiments has also been published. This other method involves using external active valves to fill the side channels.

[0008] Despite recent advances, the methods discussed above are still too limited for a large number of applications.

[0009] Therefore, what is needed is a microfluidic device that does not need active valves and has no storage limitation because it has as many side microchannels as desired. Further, what is needed is a microfluidic device in which the microchannels are geometrically designed to allow filling flow using solely capillary force, i.e., by passive pumping.

[0010] What is also needed is a device that could be used in a remote location or in a lab that has a variety of applications and many degrees of freedom.

[0011] Fabrication techniques for the current invention are generally discussed in the article entitled "Using Pattern Homogenization of Binary Grayscale Masks to Fabricate Microfluidic Structures with 3D Topography," *Lab Chip*, 2007, 7, 1567-1573, which was published in August of 2007 by the Royal Society of Chemistry, the entire contents of which are hereby expressly incorporated by reference into the present application.

SUMMARY AND OBJECTS OF THE INVENTION

[0012] By way of summary, the present invention is directed to microstructures with arbitrary topography. Preferably, the microstructures have modulated 3D topography over large areas (centimeters) and only require a single photolithographic step during fabrication. The device may further comprise at least one outlet in communication with the microchannel. The microchannel's topographic constrictions may be designed to stop priming flow through the main microchannel. These constrictions may further make use of capillary forces to move a liquid until a dead-end side channel is completely filled and a plug of liquid is stored therein. Any air (or gas) escapes through small orifices at the end of the side microchannels during this filling process. Subsequent plugs of liquid may be stored sequentially in the dead-end side channels of the device. In this way, the plugs of liquid may be used to create libraries of liquid plugs with arbitrary concentrations of chemicals. Additionally, the device may be designed to be primed passively with capillary forces.

[0013] The device may allow for complex chemical mixtures to be generated and stored for applications such as chemotaxis experiments under zero-flow conditions. The device may also allow for complex chemical mixtures to be dispersed in immiscible liquid forming droplets for combinatorial experiment or stored deterministically for subsequent analysis.

[0014] There are several possible applications of the device including the device being used in a remote location to sample water from a source. In such an application, this invention could be used for environmental sampling of liquids. For example, a person could bring one such device to a remote location and sample water from a source. The device could be designed to be primed passively with capillary forces (no external power would be required). This way the liquid sampled in the different side channels would correspond to samples acquired sequentially with a time lag between them.

[0015] This device could also be employed to realize combinatorial experiments in a lab. For example, droplets (or biological cells) could be introduced in different side channels according to a distinct property (e.g., different types of cells). The substrate could be functionalized with a gradient of proteins across the direction perpendicular to the channels, and/or with a gradient in temperature, light, etc. This device would work as a combinatorial platform with several degrees of freedom.

[0016] In another embodiment the invention is a microfluidic device without an actuator that is capable of sorting liquid plugs chronologically and storing them comprising: (1) a main microchannel with a multitude of topographic constrictions, (2) at least two inlets that merge into the main microchannel, (3) side channels with small orifices to allow any air (or gas) to escape that are associated with the topographic constrictions and alternate with the inlets, (4) and one outlet in communication with the main microchannel.

[0017] In another application of this embodiment, the device may provide for a gradient of proteins across a direction perpendicular to the channels. In another application